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AN ECONOMIC ANALYSIS OF SUSTAINABILITY IN DIFFERENT IRRIGATION REGIMES OF COIMBATORE DISTRICT

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ABSTRACT

The study was undertaken in Kinathukadavu block of Coimbatore district. A comparative study of three irrigation systems namely ground water, canal and ground water, canal irrigation system and the dry land was made covering the major crops of coconut, tomato, cowpea and black gram respectively. Sustainability of irrigation regimes was analyzed using farm level indicators and sustainable rural livelihood framework analysis.Net income was higher for tomato and coconut with ₹ 170978 and ₹ 122972. Technical efficiency was highest for canal and ground water irrigation system and canal irrigated farms has the lowest technical efficiency. Nine per cent of canal irrigated farmers are short of optimum yield and hence the yield of farmers can be increased by adopting the recommended technology. Sustainability status using farm level indicators revealed that the sustainability was high for canal and ground water and ground water irrigation system.

KEYWORDS: Cobb-Douglas Production Function, Farm Level Indicators, Resource Use Efficiency, Sustainability & Technical Efficiency

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1. INTRODUCTION

Of 324 million hectare of crop area equipped for irrigation worldwide, only 278 million hectare is actually irrigated. Among the total cultivated land, 20 per cent belongs to irrigated agriculture, but contributes 40 per cent of the total world food production. Globally, 7700 m^3 of water per hectare is withdrawn on average for irrigation annually. The world's largest irrigated crop is paddy. Conservation agriculture covers the area of 155 million hectare in the world. The irrigation system in India includes major and minor canals from Indian rivers, ground water system, tanks and other rain water harvesting projects. Out of total agricultural land, 47.70 per cent was irrigated in India. India's irrigated area is mostly equipped with ground water irrigation which is 67 per cent of total irrigation (39 million hectares). The total crop area in India is 159.60 million hectares, out of which 39.43 million hectares is ground water irrigated crop area and 22.48 million hectares is canal irrigated crop area. The total crop area actually irrigated is 58.13 million hectares. In Tamil Nadu, the total crop area covers 6.5 million hectares, in which 1.61 million hectares is irrigated using canal irrigation. The total crop area actually irrigated is 2.66 million hectares. In this present context, there is a need to obtain the optimum yield in different irrigation regimes by enhancing the agricultural sustainability and hence the present study was undertaken with the following objectives.

- To study the resource use efficiency of three irrigated ecosystem and dry land ecosystem.
- To study the technical efficiency of three irrigated systems and dry land.
- To evaluate the sustainability with farm level indicators.

2. METHODOLOGY

The study area was Kinathukadavu block of Coimbatore district which comprises of all the three irrigation ecosystems (ground water, canal and ground water and canal irrigation system) and dry land. The crops covered under the study include coconut, tomato, cowpea and black gram. A sample size of thirty five was taken in each system, so the total sample size of 140 was taken in four systems. Cobb-Douglas production function was used to analyze the resource use efficiency of four major crops of coconut, tomato, cowpea and black gram in ground water, canal and ground water, canal irrigation and dry land system respectively.

The form of regression model used in the study was

$$Y=aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} U_t$$

Where,

Y = Yield (tonnes/ha)

X_1 = Quantity of seed (kg/ha)

X_2 = Quantity of nitrogen (kg/ha)

X_3 = Quantity of phosphorus (kg/ha)

X_4 = Quantity of potassium (kg/ha)

X_5 = Machine hours (hr/ha)

X_6 = Plant protection chemicals (l/ha)

a, b_1, b_2, b_3, b_4, b_5, b_6 = Parameters to be estimated.

Data Envelopment analysis was attempted to measure the technical efficiency of ground water, canal and ground water, canal irrigation and dry land system. The Data Envelopment Analysis (DEA) is a non-parametric mathematical programming methodology based on the works of Farrell (1957) and Fraser and Cordina (1999). In this work, the following model was used to measure the technical efficiency.

$$\text{Min}_{\theta, \lambda} \theta$$

$$\text{Subject to} \quad -y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N_1 \lambda = 1$$

$$\lambda \geq 0$$

where, N_1 is a vector (n x 1) of ones.

The above model is solved each farms represented in the study. Total yield was taken as output (Y) in the present study and seed rate (kg/ha), nitrogen (kg/ha), phosphorus (kg/ha), potassium (kg/ha), machine hours (hrs/ha) and plant protection chemicals (l/ha) as inputs. The program DEAP version 2.1 which was developed by T.J. Coelli was used for the estimation of efficiencies of production in different irrigation regimes.

Indicators to assess agricultural sustainability were selected according to data availability, data sensitivity to temporal change, and the capacity of the data to quantify the behaviour of the agricultural system. Agricultural sustainability was assessed using ecological soundness, social acceptability and economic viability. Ecological sustainability refers to cropping pattern and pest and disease management. Economic viability was measured in terms of land productivity, yield stability and profitability of major crops. Social acceptability was assessed in terms of input self-sufficiency, equity and food security.

3. RESULTS AND DISCUSSIONS

3.1 Cost and Returns

The cost and returns for the major crops of three irrigation systems and the dry land were worked out and the results are given in the table 1. It could be seen from the table that the total cost of cultivation per hectare was higher for tomato followed by coconut, cowpea and black gram and it was ₹ 109212, ₹ 107406, ₹ 79570 and ₹ 41079. The gross income was highest for tomato with ₹ 280190 followed by coconut with ₹ 230378 and cowpea with ₹63005. The gross income was lowest for black gram with ₹ 24995. The net income of the crops was ₹ 170978, ₹ 122972, ₹ 16565 and ₹ 16084 for tomato, coconut, cowpea and black gram which reveals that the net income was highest for tomato. Thus it could be concluded from the table that canal and ground water system had high net returns followed by ground water system and followed by canal irrigation system and lastly with dry land system.

Table 1: Cost and Returns of Three Irrigated Ecosystem and Dry Land Crops

Particulars	Coconut	Tomato	Cowpea	Black Gram
Fixed cost	36716	33665	27483	22695
Variable cost	70690	75547	52087	18384
Total cost of cultivation	107406	109212	79570	41079
Gross income	230378	280190	63005	24995
Net income	122972	170978	16565	16084

3.2 Resource Use Efficiency

The Cobb-Douglas production function was used to estimate the output elasticity with respect to key inputs in the production of crops. The estimated Cobb-Douglas production function is furnished in table 2. It could be seen from the table that the adjusted R^2were more than 0.60 stating that the production function models were a good fit. The coefficient of seed rate, phosphorus, machine hours and plant protection chemicals were positive with the coefficient values of 0.26, 0.33, 0.44 and 0.34 respectively, which indicated that an increase in the usage of seed rate, phosphorus, machine hours and plant protection chemicals by one per cent from the existing mean level, *ceteris paribus* would increase the yield of coconut by 0.26, 0.33, 0.44 and 0.34 per cent respectively. The variable potassium was negative and indicating that one per cent change in potassium from the existing mean level, ceteris paribus would decrease the yield of coconut by 0.38 per cent.

In tomato, the yield responded significantly to the inputs such as nitrogen, phosphorus and potassium. The

coefficient of nitrogen, phosphorus and potassium were positive with the coefficient values of 0.33, 1.03 and 0.32 respectively, which indicated that an increase in the usage of nitrogen, phosphorus and potassium by one per cent from the existing mean level, *ceteris paribus* would increase the yield of tomato by 0.33, 1.03 and 0.32 per cent respectively. Thus these result indicated that the response was relatively high to the nitrogen, phosphorus and potassium. Similarly, Tambo.J.A and Gbemu.T (2010) studied resource use efficiency in tomato production in the Dangme West District of Ghana. It was reported that hired labour, pesticide and farm size were observed to affect tomato output significantly.

In cowpea, the yield responded significantly to the inputs such as seed rate, potassium, machine hours and plant protection chemicals. The coefficient of seed rate, potassium and machine hours were positive with the coefficient values of 0.84, 0.22 and 0.28 respectively, which indicated that an increase in the usage of seed rate, potassium and machine hours by one per cent from the existing mean level, *ceteris paribus* would increase the yield of cowpea by 0.84, 0.22 and 0.28 per cent respectively. The variable plant protection chemical was negative and indicating that one per cent change in plant protection chemical from the existing mean level, *ceteris paribus* would decrease the yield of cowpea by 0.38 per cent. Similar study by Omonona.B.T *et.al*,(2010) reported Farmers Resource-Use and technical efficiency in Cowpea Production in Nigeria. It was reported that farm size, cooperative membership and farming experience are the major contributing factors to the efficient production of cowpea in the state.

In black gram, the yield responded significantly to the inputs such as seed rate, phosphorus, potassium, and machine hours. The coefficient of seed rate, potassium and machine hours were positive with the coefficient values of 0.52, 0.34 and 0.35 respectively which indicated that an increase in the usage of seed rate**,** potassium and machine hours by one per cent from the existing mean level, *ceteris paribus* would increase the yield of black gram by 0.52, 0.34 and 0.35 per cent respectively. The variable phosphorus and plant protection chemicals were negative and indicating that one per cent change in phosphorus and plant protection chemicals from the existing mean level, *ceteris paribus* would decrease the yield of black gram by 0.52 and 0.16 per cent respectively. These analyses showed that the crops in different irrigation systems responded to inputs positively revealing that appropriate inputs should be used to attain the optimum yield. Similar study by Pote and Subhashrao.V (2004) studied the economics of black gram and green gram production in Latur district of Maharashtra. It was observed that regression coefficient of hired human labour, area and family human labour were 0.27, 0.52 and 0.26 respectively and highly significant at one per cent level of significance.

Table 2: Resource Use Efficiency of Three Irrigated Ecosystem and Dry Land Crops

Variables	Coconut	Tomato	Cowpea	Black Gram
Regression constant	0.21^{NS}	8.03*	1.38^{NS}	4.83**
Seed rate (kg/ha)	0.26**	0.31^{NS}	0.84**	0.52**
Nitrogen (kg/ha)	0.11^{NS}	0.33*	-0.09^{NS}	0.12^{NS}
Phosphorus (kg/ha)	0.33*	1.03*	0.15^{NS}	-0.52*
Potassium (kg/ha)	-0.38*	0.32*	0.22*	0.34**
Machine hours (hrs/ha)	0.43**	-0.64^{NS}	0.28*	0.35*
Plant protection chemicals	0.34**	-0.23^{NS}	-0.38*	-0.16^{NS}
R^2 (Adjusted)	0.91	0.88	0.69	0.83

3.3 Technical Efficiency

The Data Envelopment Analysis (DEA) is a non-parametric mathematical programming methodology used to measure the technical efficiency of irrigated ecosystems. The results of technical efficiency are presented in the table 3. It could be seen from the table that the variation in the levels of technical efficiency of ground water irrigation system ranged

from 82.00 to 100.00, canal and ground water irrigation system ranged from 81.00 to 100.00, canal irrigation system ranged from 68.00 to 100.00 and dry land system ranged from 66.00 to 100.00.The mean level of technical efficiency indicates that on an average 4.00 per cent of ground water irrigation system falling short of the maximum possible level of technology. The mean level of technical efficiency indicates that on an average three per cent of canal and ground water irrigation system falling short of the maximum possible level of technology. The mean level of technical efficiency indicates that on an average 9.00 per cent of canal irrigation system falling short of the maximum possible level of technology. The mean level of technical efficiency indicates that on an average 8.00 per cent of dry land system falling short of the maximum possible level of technology. Thus, High level of technical efficiency was observed in tomato and the level of technical efficiency was lower in cowpea.

Table 3: Technical Efficiency of Three Irrigated Ecosystem and Dry Land Crops

Parameters	Technical Efficiency			
	Ground Water	Canal And Ground Water	Canal	Dry Land
Mean	0.96	0.97	0.91	0.92
Minimum	0.82	0.81	0.68	0.66
Maximum	1	1	1	1

3.4 Indicators of Sustainability with Farm Level Indicators

Agricultural sustainability was assessed by combining the three sustainability criteria of ecological soundness, economic viability and social acceptability.

3.4.1 Ecological Sustainability

Ecological Sustainability was assessed based on cropping pattern and management of pests and diseases. Cropping pattern analyses revealed that coconut, tomato, cowpea and black gram were the major crops in ground water, canal and ground water, canal and dry land system respectively. The cropping intensity in ground water, canal and ground water, canal and dry land system was 123.94, 140.38, 116.47 and 103.24 respectively. The cropping intensity was higher in canal and ground water irrigation system. Crop diversification index for the ground water, canal and ground water, canal and dry land system was 6.75, 7.11, 7.36 and 6.01 respectively.

The pest and disease management in all the irrigation system was presented in Table 4. It could be observed from the Table that there was variation among all the irrigation systems in the management of pest and disease. In canal irrigation system, higher proportion of the farmers with 62.86 per cent followed the chemical methods for controlling pest and diseases,28.57 per cent of farmers applied both chemical and biological methods and only 8.57 percent used biological control alone. The management of pest and diseases by farmers using chemical pesticides were 60.00, 57.29 and 57.14 percent in ground water, canal and ground water and dry land system respectively. The farmers using both chemical and biological methods were 37.14, 45.71 and 42.86 percent in ground water, canal and ground water and dry land system respectively. Only 2.86 and 8.57 per cent of farmers used biological control alone in ground water and canal irrigation system respectively. It could be concluded that the farmers using both chemical and biological management were high in canal and ground water and dry land system with 45.71 per cent and 42.86 per cent respectively. The results indicated that canal and ground water system and ground water system alone was more sustainable with regard to ecological sustainability.

Table 4: Pest and Disease Management in the Sample Farms (in nos.)

Particulars	Ground Water	Canal And Ground Water	Canal	Dry Land
Chemical alone	21	19	22	20
Biological control alone	1	-	3	-
Both chemical and biological	13	16	10	15
Total	**35**	**35**	**35**	**35**

3.4.2 Economic Viability

Economic viability was assessed based on three indicators; land productivity, yield stability and profitability of crops.

3.4.2.1Productivity

The productivity of major crops is furnished in the table 5. The productivity analyses revealed that the productivity of tomato in canal and ground water irrigation system was high over ground water irrigation system by 9.13 per cent, high over canal irrigation system by 25.03 per cent and high over dry land system by 52.46 per cent. The productivity of coconut was high in ground water irrigation than canal and ground water irrigation system by 4.97 per cent. Sorghum productivity was high in ground water irrigation system when compared to canal and ground water system by 3.55 per cent, high over canal irrigation system by 24.08 per cent and high over dry land system by 40.38 per cent. The productivity of cow pea was high in ground water irrigation system as compared to canal and dry land irrigation systemby20.53 per cent and 38.37 per cent respectively**.** The productivity of black gram was higher in dry land system as compared to canal irrigation system by 5.88 per cent.

Table 5: Productivity of Major Crops (intones/ha.)

Crops	Ground Water	Canal And Ground Water	Canal	Dry Land
Tomato	18.72	20.43	16.34	13.40
Coconut	21.12	20.61	-	-
Sorghum	4.38	4.23	3.53	3.12
Cowpea	4.58	-	3.8	3.31
Black gram	-	-	0.51	0.54

3.4.2.2 Stability of Yield

The stability of crop yield was examined by constructing an index based on farmer's subjective response to a question related to yield trend. In canal and ground water irrigation system, the index of yield stability was 0.40 followed by ground water irrigation system with the yield stability of 0.32 and canal irrigation system with yield stability of 0.11. The yield stability index for dry land was -0.25 which proved that the system was unstable.

3.4.2.3 Profitability

The profitability of cropping system was analyzed based on financial and economic returns and value-addition per unit of land to understand the performance of an agricultural system. Profitability of coconut, tomato, cowpea and black gram was worked out for ground water, canal and ground water, canal and dry land system respectively since it was the major crop in these region. The results have been presented in Table 5.6.

Table 6: Profitability of Major Principle Crop in the Sample Farms (in ₹/ha)

Crops	Ground Water	Canal and Ground Water	Canal	Dry Land
Financial				
Gross return	165658	173493	79718	36082
Total variable cost	70690	75547	52087	18384
Output-input ratio	2.34	2.29	*1.53*	*1.96*
Economic				
Net return	94968	97946	27631	17698
Value-addition				
i.Cost of chemical fertilizers	21771	23800	3752	2726
ii.Cost of pesticides	5783	12000	7374	3434
iii.Cost of fuel and charge of agricultural machinery use	10102	9343	5538	3976
Cost of intermediate goods(i+ii+iii)	37656	45143	16664	10136

*Value-addition =Gross return-Cost of intermediate goods

It has been found that performance of the ground water irrigation system was better than other irrigation systems as the output-input ratio was 2.34 in ground water irrigation system followed by canal and ground water system with the output-input ratio of 2.29. Net return was higher in canal and ground water irrigation system with ₹ 97946 followed by ground water irrigation system with ₹ 94968 as net return. The value addition was found to be higher in canal and ground water irrigation system with ₹ 128350 followed by ground water irrigation system with ₹ 128002. Hence it could be concluded from the table that canal and ground water system was more sustainable followed by ground water irrigation system and canal irrigation system and lastly with dry land system. Thus the same order of sustainability was observed for economic viability

3.4.3 Social Acceptability

It was assessed in terms of input self-sufficiency, equity, and food security.

3.4.3.1 Input Self-Sufficiency

The high dependency on external inputs, such as chemical fertilizers, pesticides, and diesel and irrigation water increases farmer's vulnerability and reduces profit. The sustainability should seek to minimize dependency on external inputs. Hence, input self-sufficiency in the study area was analyzed and presented in Table 8.

Input self sufficiency of three irrigation systems and dry land are given in the table 7. It could be seen from the table that in ground water irrigation system, the dependency on local inputs was high with lower usage of local inputs, such as labour, seed, organic fertilizers and pesticides with the input self sufficiency ratio of 0.47 followed by low input self sufficiency ratios with 0.34, 0.32 and 0.35 in groundwater, canal and ground water, canal and dry land system respectively. It clearly showed that ground water system was relatively more self-sufficiency in terms of input dependency than other irrigation systems.

Table 7: Input Self-Sufficiency (in ₹/ha)

Particulars	Ground Water	Canal And Ground Water	Canal	Dry Land
Cost of all variable inputs	70690	118347	52087	18384
Cost of local inputs	33250	40621	16554	6372
Cost of external inputs	37440	77726	35533	12012
Input self-sufficiency ratio*	0.47	0.34	0.32	0.35

* Input self-sufficiency ratio = Cost of local inputs / Cost of all variable inputs

3.4.3.2 Equity

The details of equity and food security are given in table 8. It could be observed from the table that labour requirement to produce one kg of coconut was 3.6 mandays in ground water system and to produce one kg of tomato was 6.37 mandays in canal and ground water system. Similarly the labour requirement to produce one kg of cowpea was 0.17 man days in canal irrigation system and labour requirement to produce one kg of black gram was 0.15 man days in dry land system. Thereby canal and ground water irrigation system was sustainable from the equity point of view.

Table 8: Equity and Food Security

Particulars	Ground Water	Canal and Ground Water	Canal	Dry Land
Equity				
Labour requirement to produce one unit of output	3.6	6.37	0.17	0.15
Labour cost per unit of output (₹)	1080	1783	42.5	34.5
Food security				
Expenditure on food items	51328	48160	53800	45400

3.4.3.3 Food Security

Food security was measured in terms of household's food expenditure on food items. The expenditure on food items was ₹ 51328, ₹ 48160, ₹ 53800 and ₹ 45400 in ground water, canal and ground water, canal and dry land system respectively. Food expenditure in canal irrigation system was higher when compared to other irrigation systems and it is more food secure.

4. CONCLUSIONS

The net income was higher for tomato and coconut farmers. The technical efficiency was highest for canal and ground water irrigated farms and lowest for canal irrigated farms. Farm level indicators revealed that canal and ground water irrigated system was more sustainable than other irrigation regimes. Sustainable Rural livelihood analysis showed that, even though the ground water irrigation system was more sustainable with high irrigated area and equity, the physical capital has to be enhanced. The study concluded that the agricultural sustainability was high in canal and ground water irrigation system followed by ground water irrigation system.

5. POLICY IMPLICATIONS

From the above results, it could be seen that coconut, tomato, cowpea and black gram were the major crops of ground water irrigation, canal and ground water irrigation, canal and dry land system. Hence the agricultural sustainability of the farms in the respective systems can be enhanced by attaining the optimum yield in coconut, tomato, cowpea and black gram. The sustainability status revealed that the canal irrigated farmers and dry land farmers were lacking in agricultural sustainability. It could be overcome by attending suitable programs conducted by agricultural department and by adopting recommended technologies.

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